MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2210)

ETM3086 – MOBILE AND SATELLITE COMMUNICATIONS

(TE)

09 FEBRUARY 2023
9:00 A.M. – 11:00 A.M.
(2 Hours)

INSTRUCTION TO STUDENT

1. This question paper consists of 8 pages including the cover page with 4 questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the answer booklet provided.

QUESTION 1

a) Given that a total of 40MHz of bandwidth is allocated to a particular FDD cellular telephone system which uses two 25kHz simplex channels to provide full duplex voice and control channel. Calculate number of channels available per cell if a system uses 9-cell reuse and 12-cell reuse. Based on your calculation, elaborate the concept of frequency reuse for cellular mobile communication system.

[3+3 marks]

b) How many users can be supported for 1% blocking probability for the following number of trunked channels in a blocked calls cleared system?

i. 5
ii. 15
iii. 25
iv. 100

Assume that blocked calls are cleared and each user generates 0.1 Erlangs of traffic.

[2+2+2+2 marks]

c) By comparing to other cell shape such as square and equilateral triangle, cellular system designers prefer to use the regular hexagon to approximate the cells. State **THREE** reasons for this preference.

[3 marks]

d) In a 7-cell repeating pattern, as shown in **Figure Q1** below,

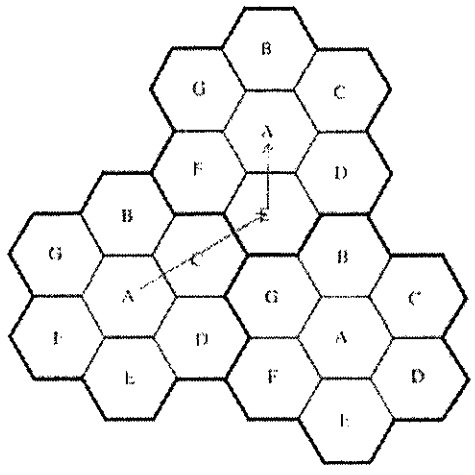


Figure Q1

Continued...

i. Calculate the frequency reuse factor Q and the signal-to-interference ratio (SIR)?

ii. Find SIR improvement if directional antennas are located at each base station in such a way that each antenna covers an angle of 120 degrees and 60 degrees.

Assume equal transmitter powers, pathloss exponent n = 4, and equal co-channel separations.

[4+4 mark]

QUESTION 2

a) Discuss the importance of path loss prediction model. Also, describe the difference between large scale and small scale propagation model.

[4 marks]

b) Explain in detail **THREE** significant wave propagation mechanisms that may affect propagation of electromagnetic waves in Non-line-of-sight (NLOS) urban environment at 5.8GHz.

[9 marks]

c) A base station has a 900MHz transmitter and a vehicle is moving at 80km/h. Compute the received carrier frequency if the vehicle is moving
(i) Directly towards the base station.

[3 marks]

(ii) Directly away from the base station.

[2 marks]

d) For the power delay profile as shown in **Figure Q2** below, find:

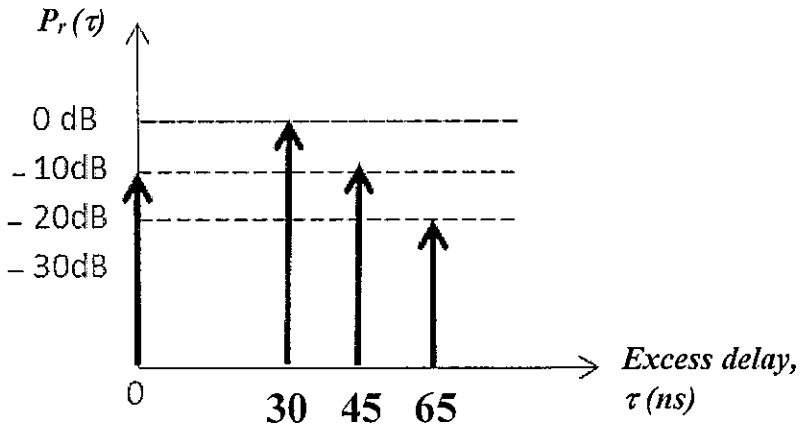


Figure Q2

Continued...

Hint: $\bar{\tau} = \frac{\sum_k a_k^2 \tau_k}{\sum_k a_k^2} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)}$, $\tau^2 = \frac{\sum_k a_k^2 \tau_k^2}{\sum_k a_k^2} = \frac{\sum_k P(\tau_k)\tau_k^2}{\sum_k P(\tau_k)}$,

$\sigma_\tau = \sqrt{\tau^2 - (\tau)^2}$

(i) Mean excess delay
(ii) RMS delay spread
(iii) 50% coherence bandwidth.

[2+3+2 marks]

QUESTION 3

a) The attenuation by rain can cause the satellite signal strength drops significantly. Propose two mitigation techniques to improve the communication performance.

[4 marks]

b) A geostationary satellite carries a transponder transmitting at 4 GHz. The transmitter is operated at an output power of 10 watts and drives an antenna with a gain of 30 dB. An earth station is at the center of the coverage zone of the satellite, at a range of 38,500 km. Using decibels for all calculations, find:

(i) The flux density at the earth station in dBW/m^2
(ii) The power received by a receive antenna with a gain of 39 dBi, in dBW.
(iii) The effective isotropic radiated power (EIRP) of the transponder in dBW.

[4+3+2 marks]

c) A C-band earth station has an antenna with a transmit gain of 54 dB. The transmitter output power is set to 100 W at a frequency of 6.1 GHz. The signal is received by a satellite at a distance of 37,500 km by an antenna with a gain of 26 dBi. The signal is then routed to a transponder with a noise temperature of 500 K, a bandwidth of 36 MHz, and a gain of 110 dBi

(i) Calculate the path loss at 6.1 GHz. Wavelength is 0.04918 m.
(ii) Calculate the power at the output port (sometimes called the output waveguide flange) of the satellite antenna, in dBW.
(iii) Calculate the noise power at the transponder input, in dBW, in a bandwidth of 36 MHz.
(iv) Calculate the C/N ratio, in dB, in the transponder.
(v) Calculate the carrier power, in dBW and in watts, at the transponder output.

[2+2+2+3+3 marks]

Continued...

QUESTION 4

a) A low earth orbit satellite constellation consists of a few satellites in circular earth orbits with an altitude of 1000 km. Answer the following questions about the constellation.

(i) Calculate the orbital period of a satellite.

(ii) Communication between an earth station and a satellite is restricted to times when the satellites are at an elevation of 8 degrees or more. Find the maximum coverage area served by one satellite. (Hint: the solid angle of a cone with apex angle 2θ is $\Omega = 2\pi(1 - \cos\theta)$)

(iii) Estimate the number of satellites required to provide simultaneous worldwide coverage.

[4+6+2 marks]

b) Describe the differences between the low earth orbit (LEO) and the highly elliptical orbit (HEO) on these aspects:

(i) Path loss
(ii) Propagation delay
(ii) Spectrum reuse efficiency
(iii) Duration of satellite visibility

[4 marks]

c) A GEO satellite orbits the earth directly over the equator which has an orbital period of 23 hours 56 minutes and 4.09 seconds.

(i) By using Kepler's law, calculate the semi-major axis of the satellite orbit and altitude of the satellite.

(ii) If the GEO satellite is operating at frequency of 6GHz, determine the free space path loss of this satellite to the Earth station and the round trip propagation delay.

[6+3marks]

Continued...

Appendix I: Constant values

Gravitation parameter, μ	=	3.986×10^{14} m^3/s^2
Mean Earth radius, R_E	=	6378 km
Speed of light, c	=	3×10^8 m/s
Sidereal day	=	23h 56m 4.09s
Boltzmann constant, k	=	1.379×10^{-23} J/K = -228.6 dBW/Hz K

Appendix II: Table of Complementary Error Function

$$erfc(z) = \frac{2}{\sqrt{\pi}} \int_z^{\infty} e^{-t^2} dt \quad \text{for } 0 \le z \le 3.99 \text{ in steps of } 0.01$$

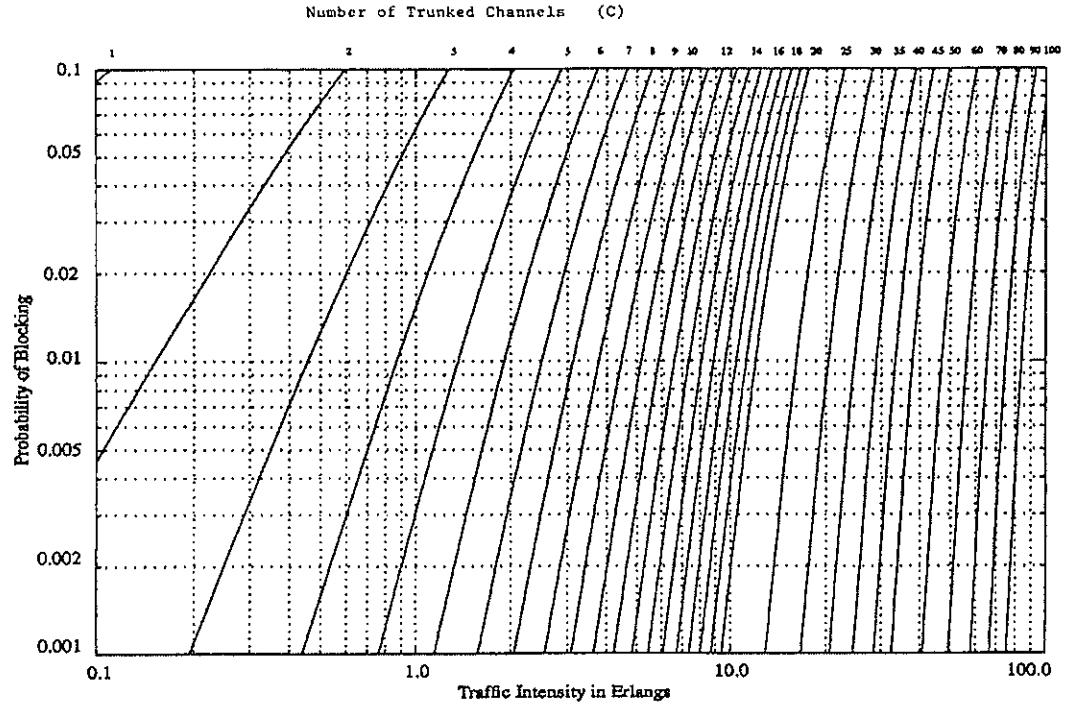
z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000E+00	9.887E-01	9.774E-01	9.662E-01	9.549E-01	9.436E-01	9.324E-01	9.211E-01	9.099E-01	8.987E-01
0.1	8.875E-01	8.764E-01	8.652E-01	8.541E-01	8.431E-01	8.320E-01	8.210E-01	8.100E-01	7.991E-01	7.882E-01
0.2	7.773E-01	7.665E-01	7.557E-01	7.450E-01	7.343E-01	7.237E-01	7.131E-01	7.026E-01	6.921E-01	6.817E-01
0.3	6.714E-01	6.611E-01	6.509E-01	6.407E-01	6.306E-01	6.206E-01	6.107E-01	6.008E-01	5.910E-01	5.813E-01
0.4	5.716E-01	5.620E-01	5.525E-01	5.431E-01	5.338E-01	5.245E-01	5.153E-01	5.063E-01	4.973E-01	4.883E-01
0.5	4.795E-01	4.708E-01	4.621E-01	4.535E-01	4.451E-01	4.367E-01	4.284E-01	4.202E-01	4.121E-01	4.041E-01
0.6	3.961E-01	3.883E-01	3.806E-01	3.730E-01	3.654E-01	3.580E-01	3.506E-01	3.434E-01	3.362E-01	3.292E-01
0.7	3.222E-01	3.153E-01	3.086E-01	3.019E-01	2.953E-01	2.888E-01	2.825E-01	2.762E-01	2.700E-01	2.639E-01
0.8	2.579E-01	2.520E-01	2.462E-01	2.405E-01	2.349E-01	2.293E-01	2.239E-01	2.186E-01	2.133E-01	2.082E-01
0.9	2.031E-01	1.981E-01	1.932E-01	1.884E-01	1.837E-01	1.791E-01	1.746E-01	1.701E-01	1.658E-01	1.615E-01
1.0	1.573E-01	1.532E-01	1.492E-01	1.452E-01	1.414E-01	1.376E-01	1.339E-01	1.302E-01	1.267E-01	1.232E-01
1.1	1.198E-01	1.165E-01	1.132E-01	1.100E-01	1.069E-01	1.039E-01	1.009E-01	9.800E-02	9.516E-02	9.239E-02
1.2	8.969E-02	8.704E-02	8.447E-02	8.195E-02	7.949E-02	7.710E-02	7.476E-02	7.249E-02	7.027E-02	6.810E-02
1.3	6.599E-02	6.394E-02	6.193E-02	5.998E-02	5.809E-02	5.624E-02	5.444E-02	5.269E-02	5.098E-02	4.933E-02
1.4	4.771E-02	4.615E-02	4.462E-02	4.314E-02	4.170E-02	4.030E-02	3.895E-02	3.763E-02	3.635E-02	3.510E-02
1.5	3.389E-02	3.272E-02	3.159E-02	3.048E-02	2.941E-02	2.838E-02	2.737E-02	2.640E-02	2.545E-02	2.454E-02
1.6	2.365E-02	2.279E-02	2.196E-02	2.116E-02	2.038E-02	1.962E-02	1.890E-02	1.819E-02	1.751E-02	1.685E-02
1.7	1.621E-02	1.559E-02	1.500E-02	1.442E-02	1.387E-02	1.333E-02	1.281E-02	1.231E-02	1.183E-02	1.136E-02
1.8	1.091E-02	1.048E-02	1.006E-02	9.653E-03	9.264E-03	8.889E-03	8.528E-03	8.179E-03	7.844E-03	7.521E-03
1.9	7.210E-03	6.910E-03	6.622E-03	6.344E-03	6.077E-03	5.821E-03	5.574E-03	5.336E-03	5.108E-03	4.889E-03
2.0	4.678E-03	4.475E-03	4.281E-03	4.094E-03	3.914E-03	3.742E-03	3.577E-03	3.418E-03	3.266E-03	3.120E-03
2.1	2.979E-03	2.845E-03	2.716E-03	2.593E-03	2.475E-03	2.361E-03	2.253E-03	2.149E-03	2.049E-03	1.954E-03
2.2	1.863E-03	1.776E-03	1.692E-03	1.612E-03	1.536E-03	1.463E-03	1.393E-03	1.326E-03	1.262E-03	1.201E-03
2.3	1.143E-03	1.088E-03	1.034E-03	9.838E-04	9.354E-04	8.893E-04	8.452E-04	8.032E-04	7.631E-04	7.249E-04
2.4	6.885E-04	6.538E-04	6.207E-04	5.892E-04	5.592E-04	5.306E-04	5.034E-04	4.774E-04	4.528E-04	4.293E-04
2.5	4.070E-04	3.857E-04	3.655E-04	3.463E-04	3.280E-04	3.107E-04	2.942E-04	2.785E-04	2.636E-04	2.495E-04
2.6	2.360E-04	2.233E-04	2.112E-04	1.997E-04	1.888E-04	1.785E-04	1.687E-04	1.594E-04	1.506E-04	1.422E-04
2.7	1.343E-04	1.268E-04	1.197E-04	1.130E-04	1.066E-04	1.006E-04	9.492E-05	8.952E-05	8.441E-05	7.958E-05
2.8	7.501E-05	7.069E-05	6.661E-05	6.275E-05	5.910E-05	5.566E-05	5.240E-05	4.933E-05	4.642E-05	4.368E-05
2.9	4.110E-05	3.866E-05	3.635E-05	3.418E-05	3.213E-05	3.020E-05	2.838E-05	2.667E-05	2.505E-05	2.353E-05
3.0	2.209E-05	2.074E-05	1.947E-05	1.827E-05	1.714E-05	1.608E-05	1.508E-05	1.414E-05	1.326E-05	1.243E-05
3.1	1.165E-05	1.092E-05	1.023E-05	9.578E-06	8.970E-06	8.398E-06	7.862E-06	7.358E-06	6.885E-06	6.442E-06
3.2	6.026E-06	5.635E-06	5.269E-06	4.926E-06	4.604E-06	4.303E-06	4.020E-06	3.755E-06	3.507E-06	3.275E-06
3.3	3.058E-06	2.854E-06	2.664E-06	2.485E-06	2.319E-06	2.162E-06	2.017E-06	1.880E-06	1.753E-06	1.633E-06
3.4	1.522E-06	1.418E-06	1.321E-06	1.230E-06	1.145E-06	1.066E-06	9.922E-07	9.233E-07	8.590E-07	7.990E-07
3.5	7.431E-07	6.910E-07	6.423E-07	5.970E-07	5.548E-07	5.155E-07	4.788E-07	4.447E-07	4.130E-07	3.834E-07
3.6	3.559E-07	3.303E-07	3.064E-07	2.843E-07	2.636E-07	2.445E-07	2.267E-07	2.101E-07	1.947E-07	1.804E-07
3.7	1.672E-07	1.548E-07	1.434E-07	1.327E-07	1.229E-07	1.137E-07	1.052E-07	9.736E-08	9.005E-08	8.328E-08
3.8	7.700E-08	7.119E-08	6.579E-08	6.080E-08	5.617E-08	5.189E-08	4.792E-08	4.425E-08	4.085E-08	3.770E-08
3.9	3.479E-08	3.210E-08	2.961E-08	2.731E-08	2.518E-08	2.322E-08	2.140E-08	1.972E-08	1.817E-08	1.674E-08

Note: 1.000E-01 = 1.000×10^{-1}

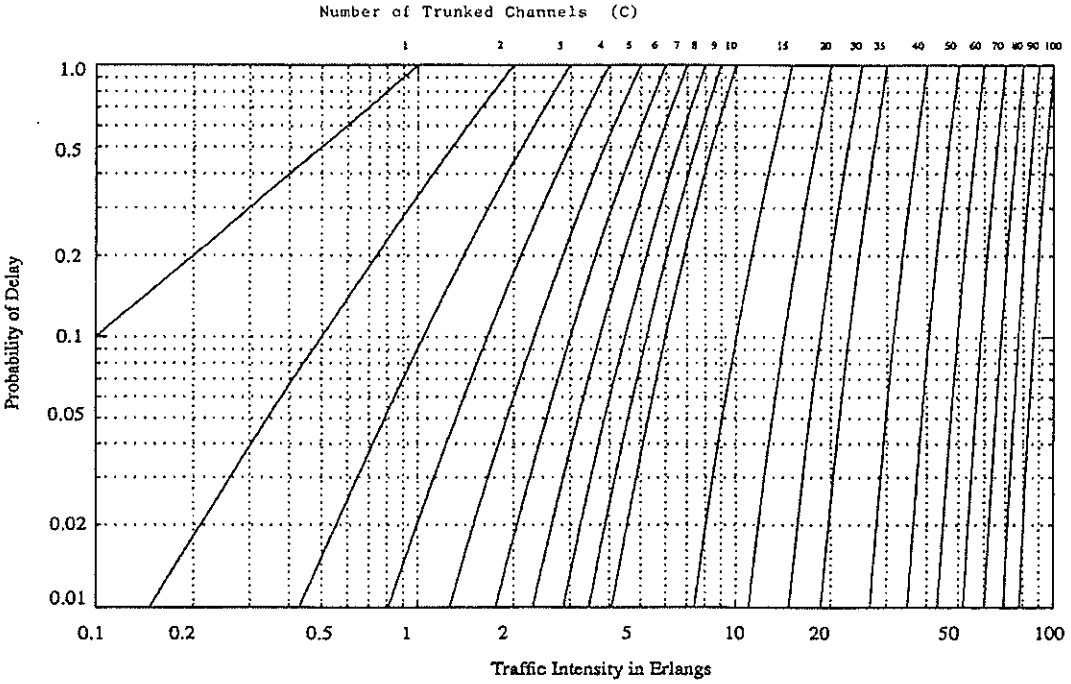
For $z > 4$, $\quad erfc(z) \approx \frac{1}{\sqrt{\pi}} \left(\frac{e^{-z^2}}{z} \right)$

Continued...

Appendix III: Erlang B and Erlang C Chart



The Erlang B chart showing the probability of blockings as functions of the number of channels and traffic intensity in Erlangs.



The Erlang C chart showing the probability of a call being delayed as a function of the number of channels and traffic intensity in Erlangs.

Continued...

Appendix IV: Formulae

Remarks: The general formulae below may need to be modified according to the context.

$$v_S = \sqrt{\frac{\mu}{a}\left(\frac{2a}{r_o} - 1\right)} \qquad SIR = \frac{P_r}{\sum_{i=1}^{K} P_i} = \frac{1}{\sum_{i=1}^{K} \frac{1}{\left(\frac{D_i}{R}\right)^n}} \qquad T^2 = \frac{4\pi^2 a^3}{\mu} \qquad r = \frac{a\left(1-e^2\right)}{1+e\cdot\cos(\theta)}$$

$$b = a\sqrt{1-e^2}$$

Antenna

Effective isotropic radiated power, $EIRP = P_t G_t$

Power flux density, $\phi = \frac{EIRP}{4\pi R^2}$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter D:

$$G_{\max} = \left(\frac{4\pi}{\lambda^2}\right) A_{eff} = \eta\left(\frac{\pi D}{\lambda}\right)^2 = \eta\left(\frac{70\pi}{\theta_{3dB}}\right)^2, \text{ where } \theta_{3dB} = 70\left(\frac{\lambda}{D}\right)$$

Link Analysis

Received power, $[P_r] = [EIRP] + [G_r] - [L_{Total}]$

Free space loss, $L_{FS} = \left(\frac{4\pi R}{\lambda}\right)^2$

Noise power spectral density, $N_o = kT$

Noise factor, $F = 1 + \frac{T_e}{T_o}$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \ldots + \frac{T_{en}}{G_1 G_2 \ldots G_{n-1}}$$

FDM-FM-FDMA Satellite System

Signal bandwidth, $B = 2(gl\Delta f_{rms} + f_{max})$

where $\log_{10} l = \begin{cases} (-1 + 4\log_{10} n)/20, & n \le 240 \\ (-15 + 10\log_{10} n)/20, & n > 240 \end{cases}$

Relationship between C/N and S/N is given by:

$$\frac{C}{N} = \left(\frac{S}{N}\right)\left(\frac{b}{B}\right)\left(\frac{f_{\max}}{\Delta f_{rms}}\right)^2 \frac{1}{pw}$$

End of Paper

AAA